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Prediction of non-propagating cracks initiated from 3D notches

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ABSTRACT

Non-propagation of surface cracks in constant-amplitude loading has been widely observed empirically [3, 5]. The phenomenon is linked to the well-known short crack problem; short cracks have been observed to propagate at a faster rate compared to equivalent long cracks. It is also known that crack closure reduces crack driving force, but needs a certain crack propagation length to become effective [2, 4]. On top of this, cracks initiating at a notch are affected by the notch plasticity field, which can delay crack closure saturation. Considering these findings, it appears that the phenomena of crack closure and crack arrest are linked.

Plasticity-induced crack closure is intrinsic to Mode I crack propagation in metals and can be considered the baseline of premature crack closure influence [2, 1]. Present work attempts to determine the role of plasticity-induced crack closure in crack non-propagation behavior. The purpose is to gain understanding of mechanisms affecting fatigue crack propagation and non-propagation. Additionally, present work aims at enhancing numerical fatigue research methods, which allow for obtaining data difficult or impossible to obtain from traditional fatigue testing, with a fraction of the cost.

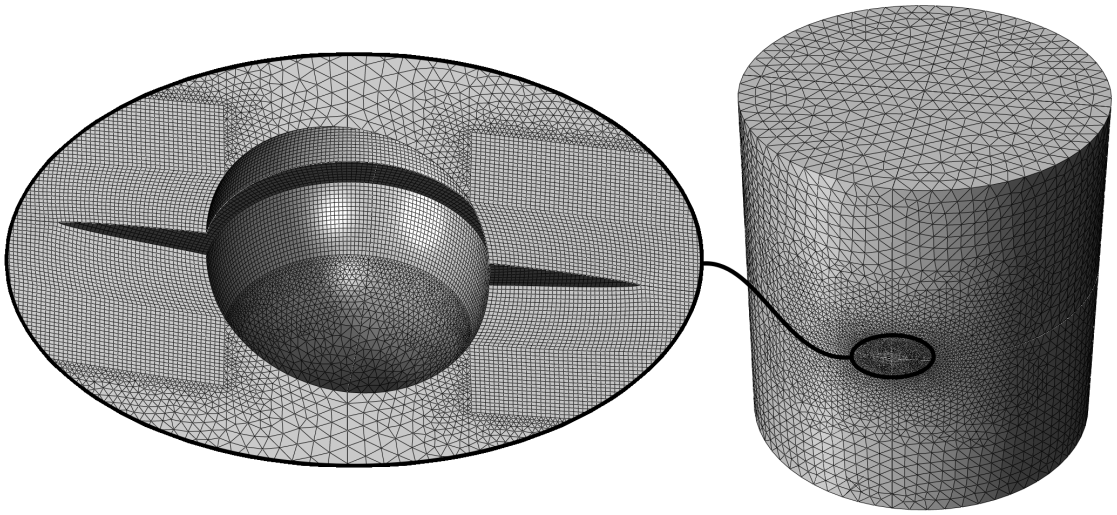

Figure 1. Visualization of the modeled test specimen.

In present work, extensive elastic-plastic finite element analysis of near-threshold propagation of short cracks nucleating from surface defects is presented. Non-propagation behavior is typical for surface defect initiated fatigue cracks. The modeled test specimen geometry is a circular cylinder with a microscopic hemispherical pit representing the surface defect (Fig. 1). Existing three-dimensional finite element model allows for the detailed studying of fatigue crack propagation and plasticity-induced crack closure.

It is shown that plasticity-induced crack closure is very significant in surface defect initiated cracks. On the surface, it can so much as halve the crack-tip opening span. Differences in plasticity-induced closure along the transition from plane stress to plane strain define the opening profile of the growing 3D crack and contribute to the shape of the crack front. Delayed development of plasticity-induced crack closure seems to significantly promote crack non-propagation behavior.

Keywords: fatigue and fracture, plasticity-induced crack closure, crack arrest, finite element method, material defect.

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